STAR Run18 Report

J.H. Lee
(for the STAR Collaboration)

BNL

RHIC AGS Users' Meeting 2018

Outline

- Beam Use Requests / Physics program
- STAR detector and upgrades for Run18
- STAR operation, performance & datasets
- Summary

Run18 Beam Use Requests

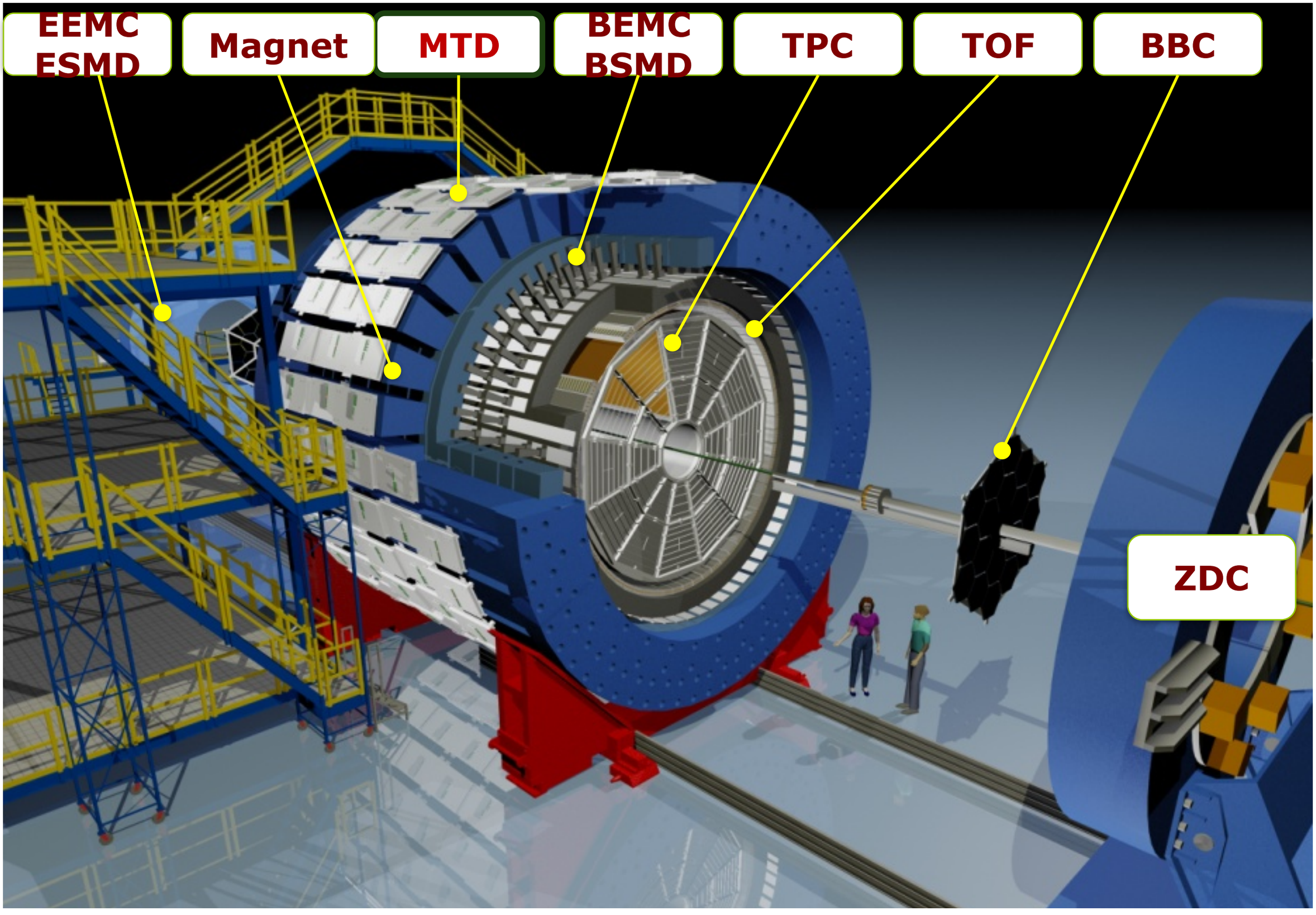
Energy	Duration	System	Goals	priority	Sequence
$\sqrt{s_{NN}}$=200 GeV	3.5-wk	Zr+Zr	1.2B min-bias	1	1
	3.5-wk	Ru+Ru	1.2B min-bias	1	2
$\sqrt{s_{NN}}$=27 GeV	3-wk	Au+Au	1B min-bias	2	3
$\sqrt{s_{NN}}$=3 GeV(FXT)	2 days	Au+Au	100M min-bias	3	4

Assuming 15 cryo-weeks of running (including CeC test)

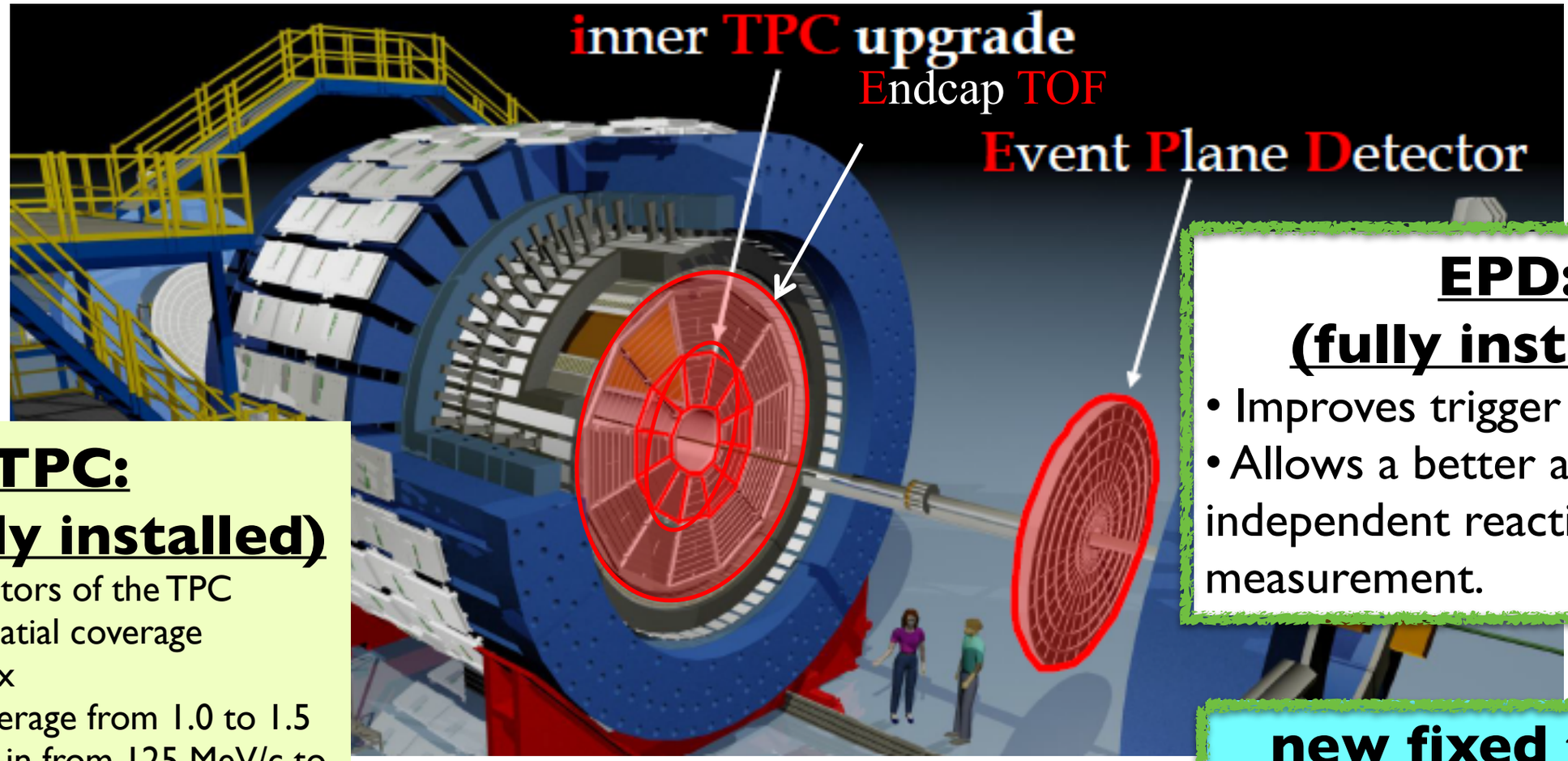
BUR: Key physics goals

- **Isobar collisions at $\sqrt{s_{NN}}$=200 GeV**
  - Chirally restored quarks with topological anomaly separated along magnetic field
  - Study the Chiral Magnetic Effect in Ru+Ru(44,96) and Zr+Zr(40,96)
    - 10% difference in magnetic field, everything else the same. Discriminating CME signal from background (5σ)
- **Au+Au at $\sqrt{s_{NN}}$=27 GeV**
  - Global angular momentum transfer (vortical coupling) to hyperon polarization
  - High statistics, high precision Lambda, anti-Lambda polarization measurement with respect to event plane
  - (potentially) Direct measurement of magnetic field (3σ) from the polarization difference of Lambda and anti-Lambda
- **Au+Au at $\sqrt{s_{NN}}$=3 GeV**
  - Fluctuation measurement at energies between HADES (2.2 GeV) and BES-I (7.7 GeV)
  - High statistics in fixed target mode with large acceptance

STAR Detector System



New addition to Run18



iTPC:
(partially installed)

- New inner sectors of the TPC
- Continuous spatial coverage
- Improves dE/dx
- Extends η coverage from 1.0 to 1.5
- Lowers p_T cut-in from 125 MeV/c to 60 MeV/c

EPD:
(fully installed)

- Improves trigger
- Allows a better and independent reaction plane measurement.

new fixed target
(installed)

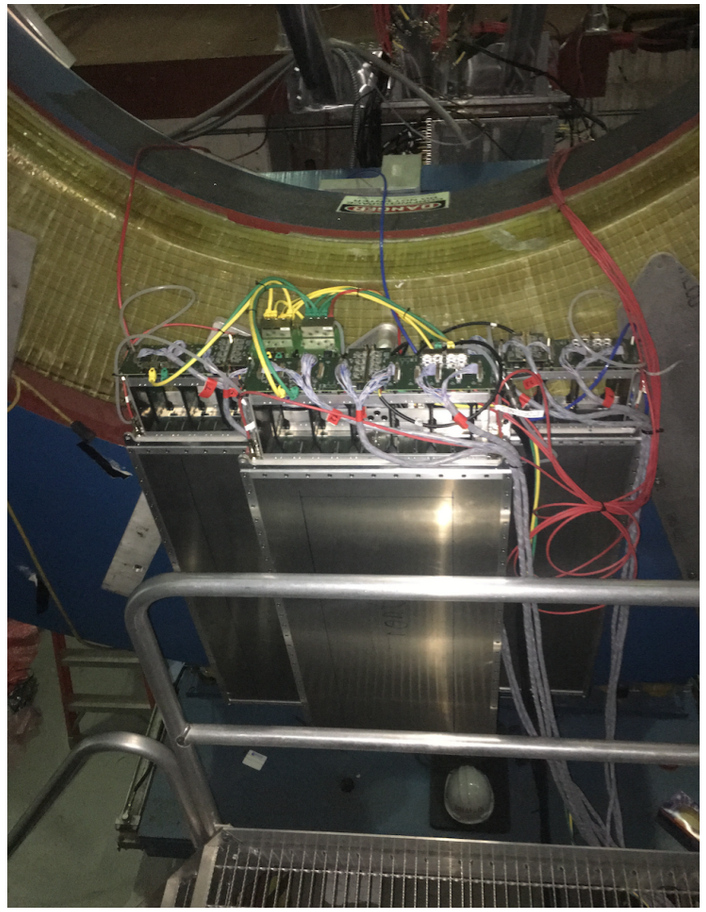
- Thinner target for reduced pile-up

Endcap TOF:
(partially installed)

- PID at η = 0.9 to 1.5
- Improves the fixed target program
- Provided by CBM-FAIR Phase0

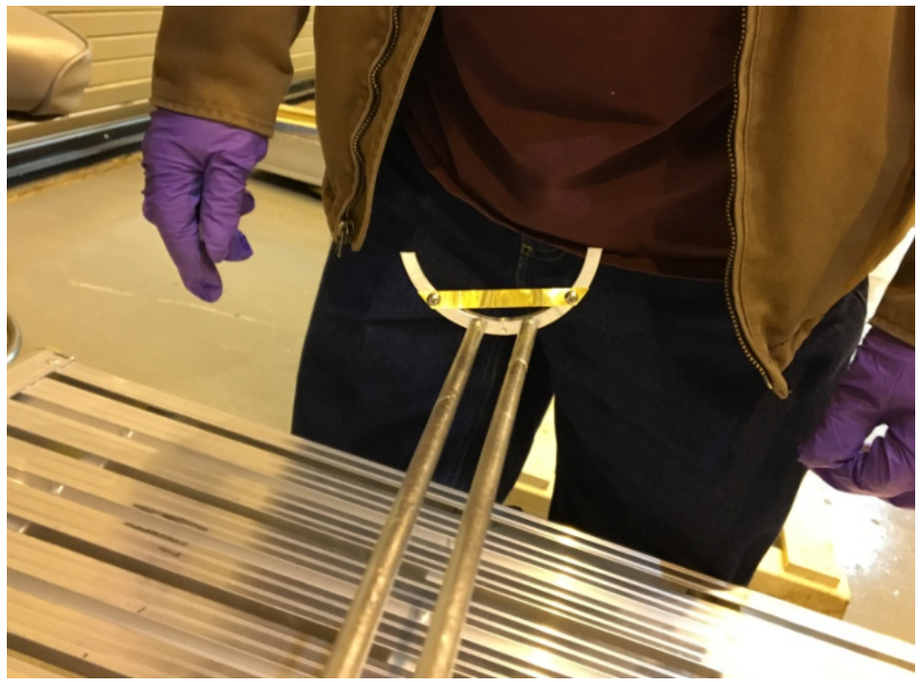
Run18: 1 iTPC (/24) sector and 3 ETOF (/36) modules for full scale test before complete installation

EPD (full installation)



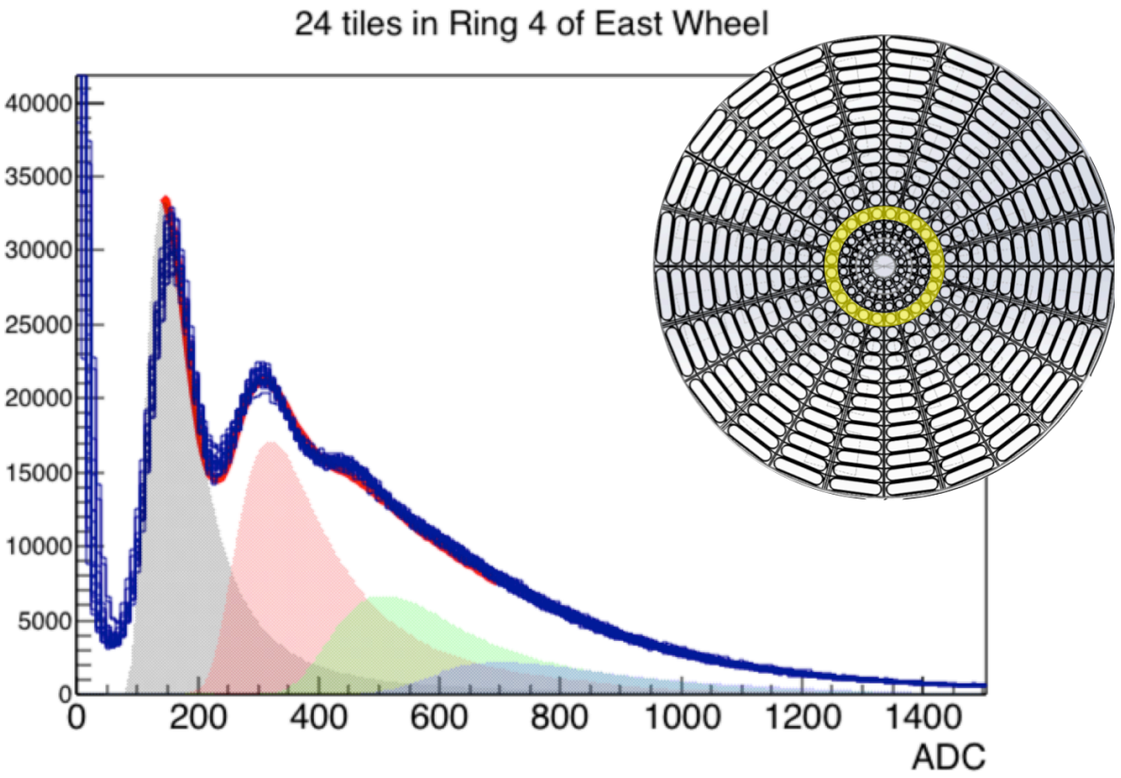
ETOF (3 modules)

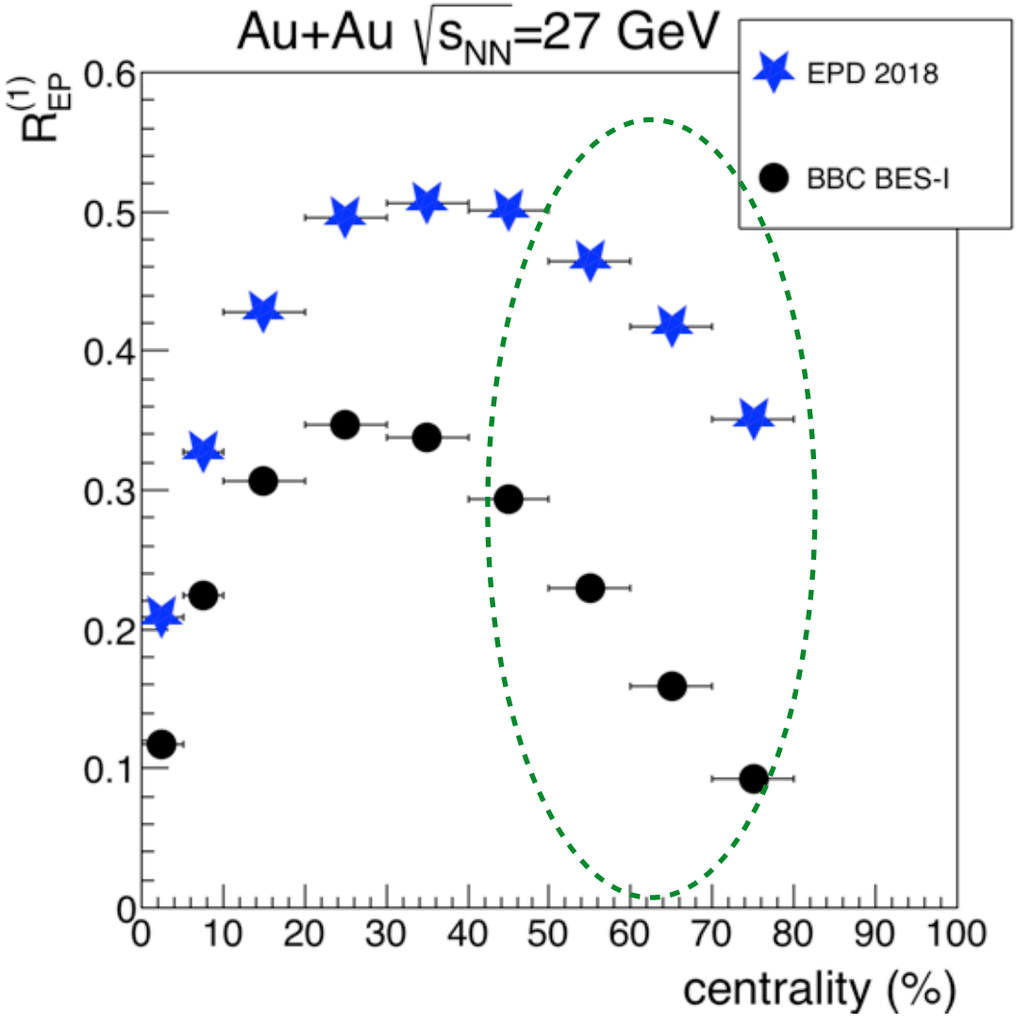
iTPC Sector & Electronics



new Au Fixed target

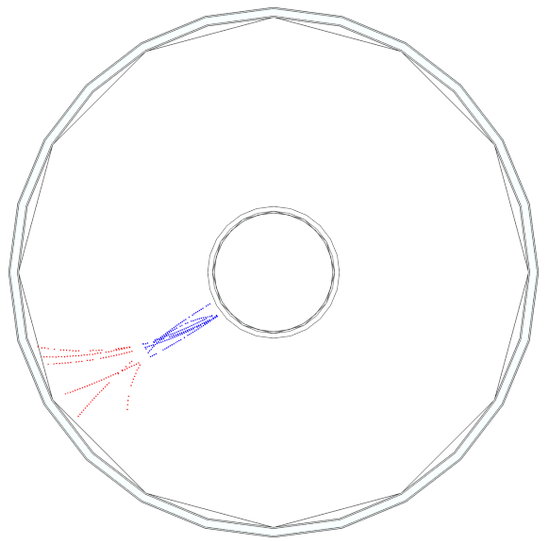
EPD performance: enhanced event plane resolution

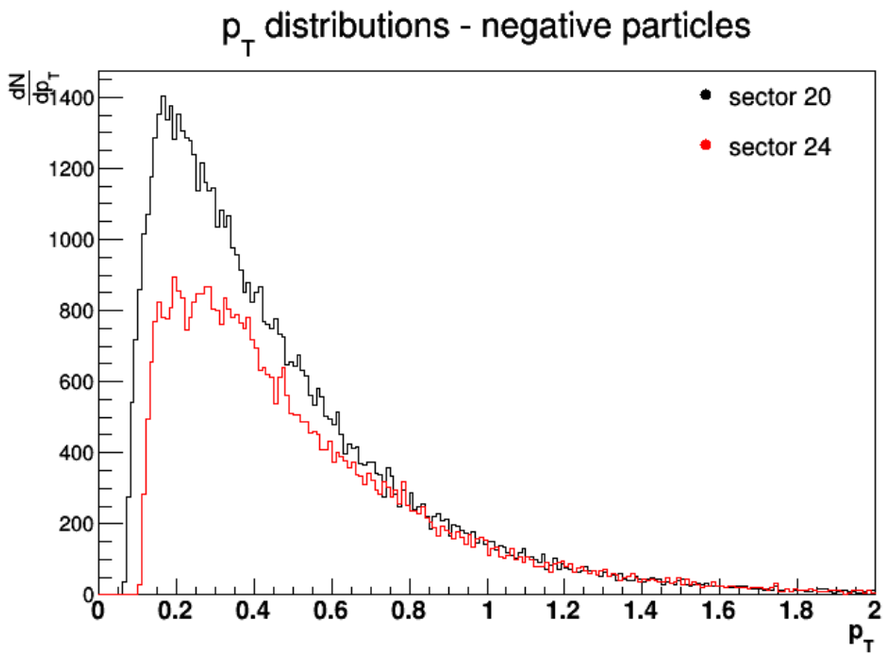


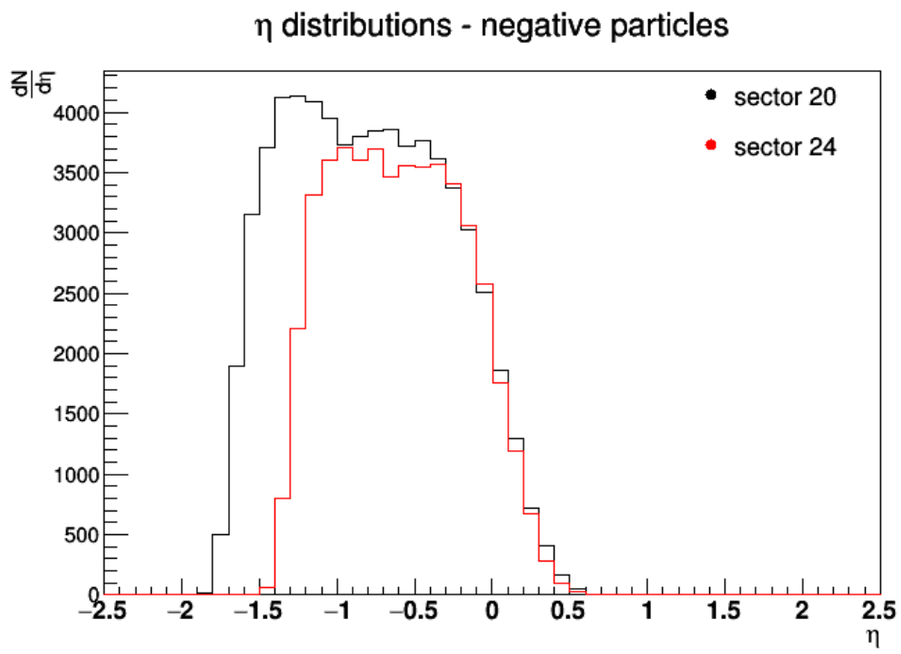


- Fully installed 16 radial and 24 azimuthal sections covering $2.1<|\eta|<5$
- Integrated and operational from the first day of the run
- Extremely uniform response
- Event plane resolution greatly improved especially for peripheral collisions
  - Lambda polarization uncertainty $\delta\mathcal{P} \sim \frac{1}{R_{\mathrm{EP}}^{(1)} \times \sqrt{N}}$

iTPC performance:
enhanced acceptance and resolution



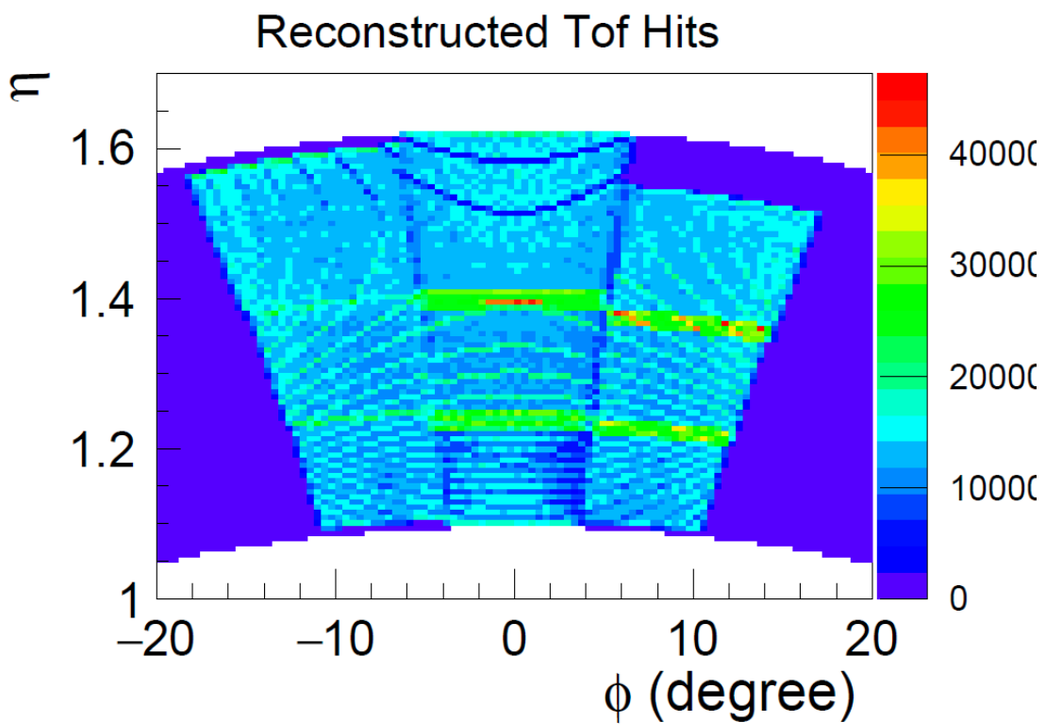


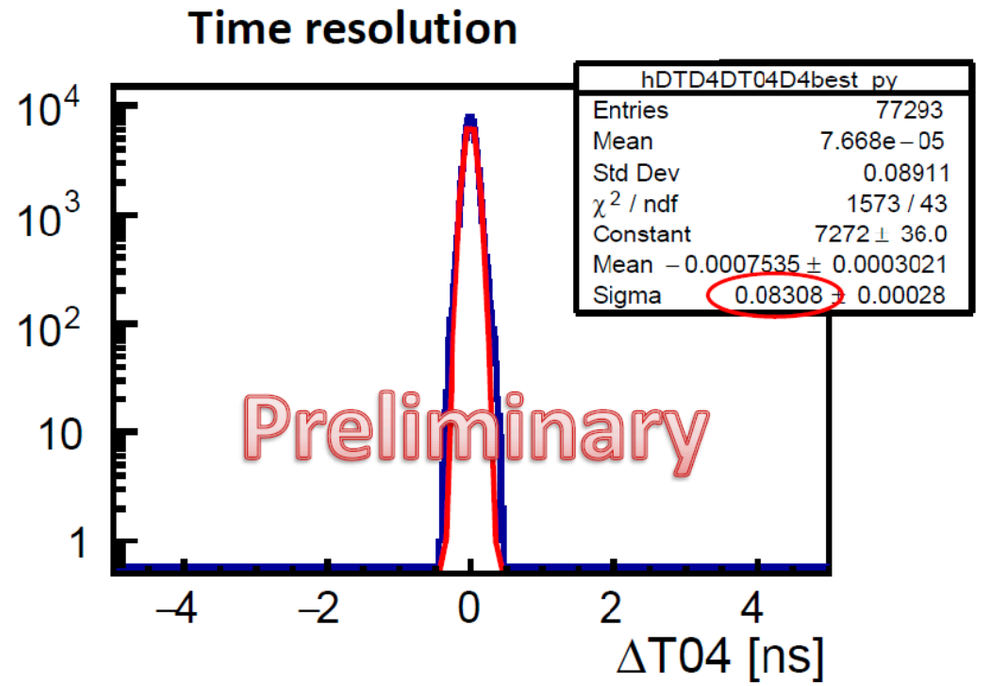


Comparing tracking of iTPC sector (20) vs standard sector (24)

- 1(/24) sector installed and successfully operated in Run18
- performance reaching expectation
- Complete installation of 24 sectors before Run19

endcap TOF performance: enhanced forward PID



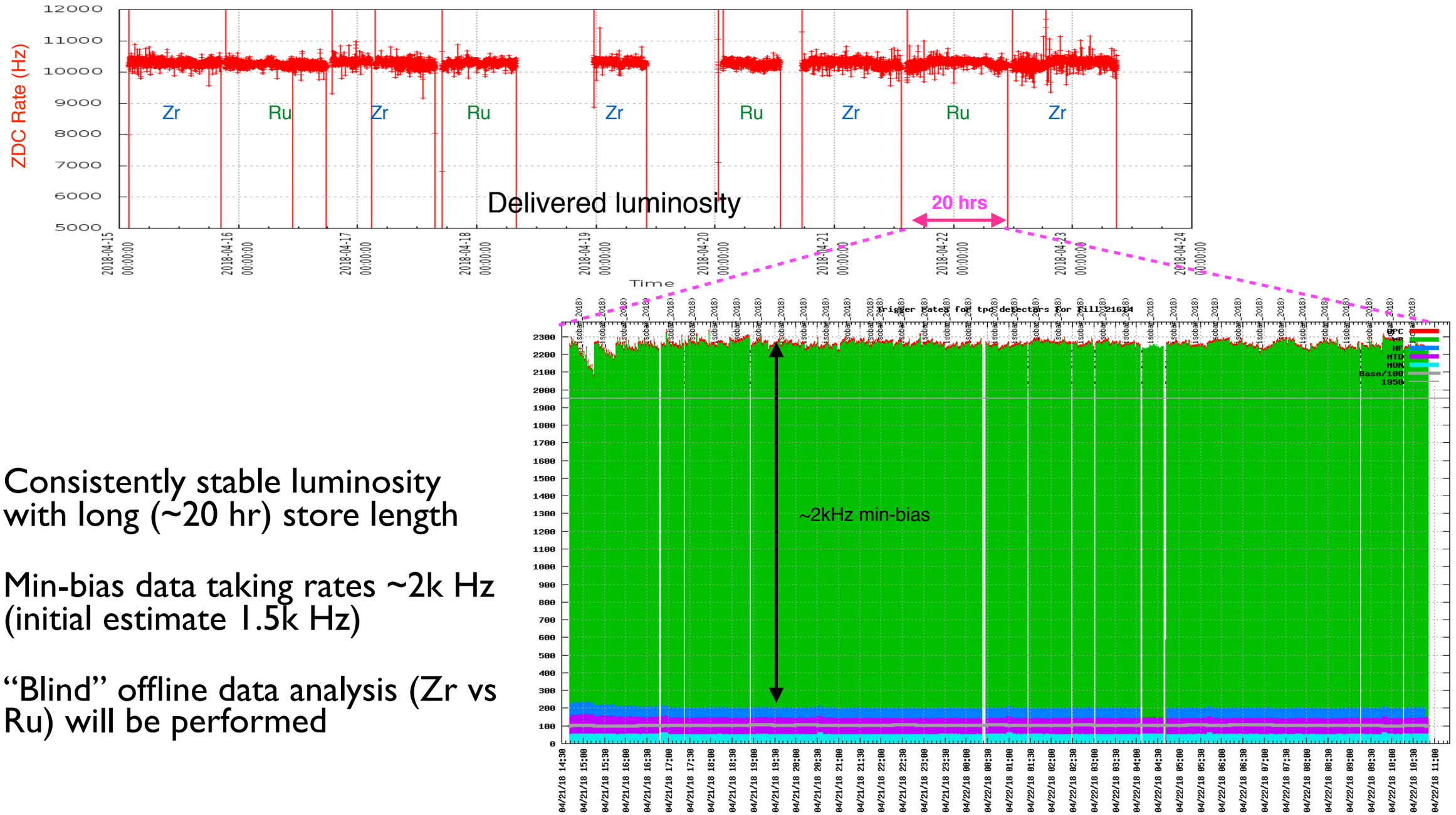


- 3(/36) modules (-1.5<η<-1.1) commissioned and participated in data taking
- 59 ps counter timing resolution obtained
- complete installation in November 2018

Data taking for isobar collisions: ZrZr, RuRu at $\sqrt{s_{NN}}$=200 GeV -Requested and performed

- Optimized luminosity: maximum STAR data acquisition rate and minimum background and pile-up
  - Stable luminosity leveling at ZDC ~10K Hz ($\mathcal{L}$~2.2 x $10^{27}cm^{-2}s^{-1}$)
  - Stochastic beam cooling to control emittance
- Rapid (~daily) switching between Ru and Zr: minimize systematic uncertainties
  - 20 hr/store/isobar
- Maximize the purity and reconstruction efficiency: min-bias trigger with tight vertex cut (with VPD ±30cm)

Data taking for isobar collisions: ZrZr, RuRu at $\sqrt{s_{NN}}$=200 GeV

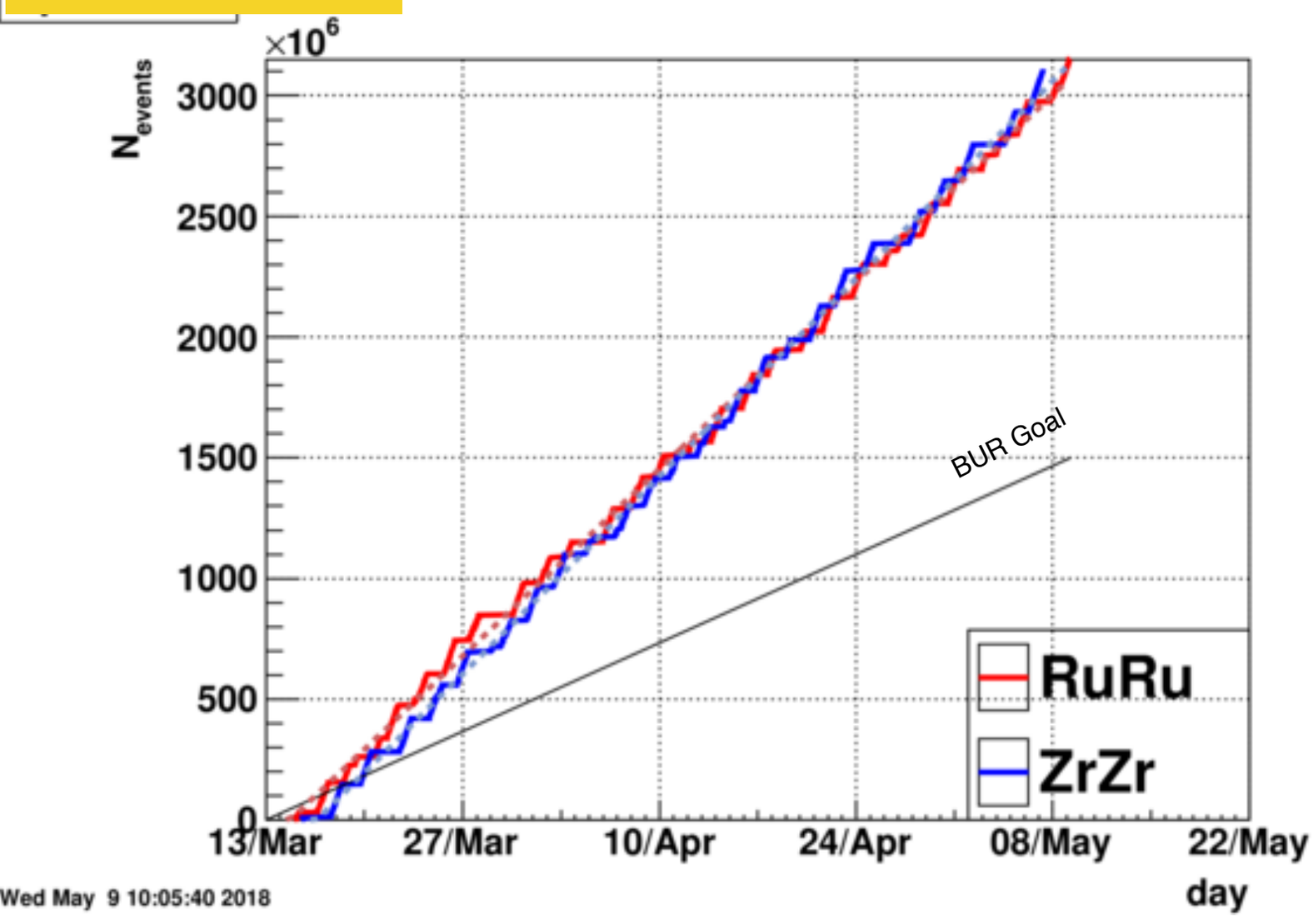


STAR Data Acquisition Rates

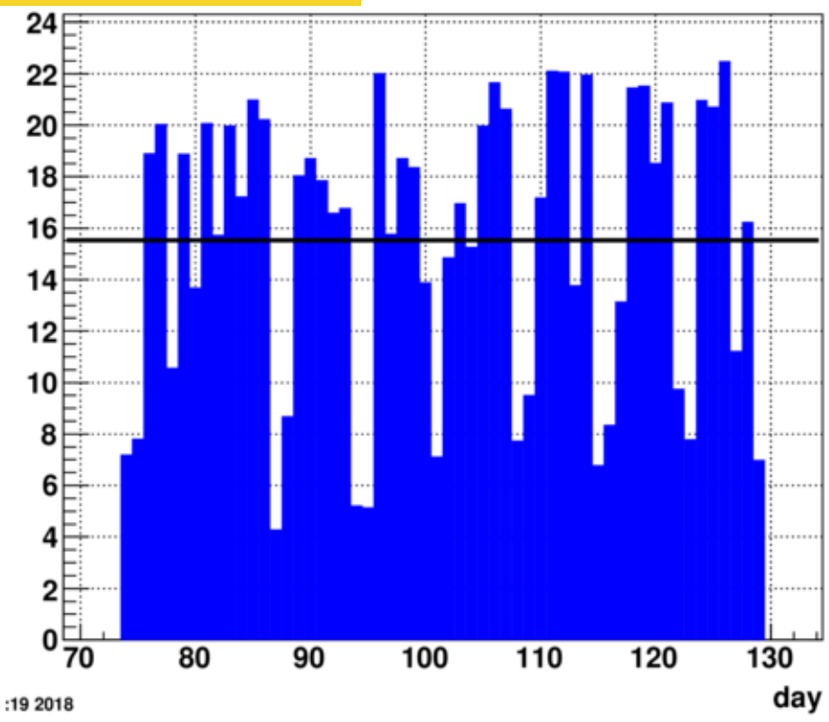
- Consistently stable luminosity with long (~20 hr) store length
- Min-bias data taking rates ~2k Hz (initial estimate 1.5k Hz)
- "Blind" offline data analysis (Zr vs Ru) will be performed

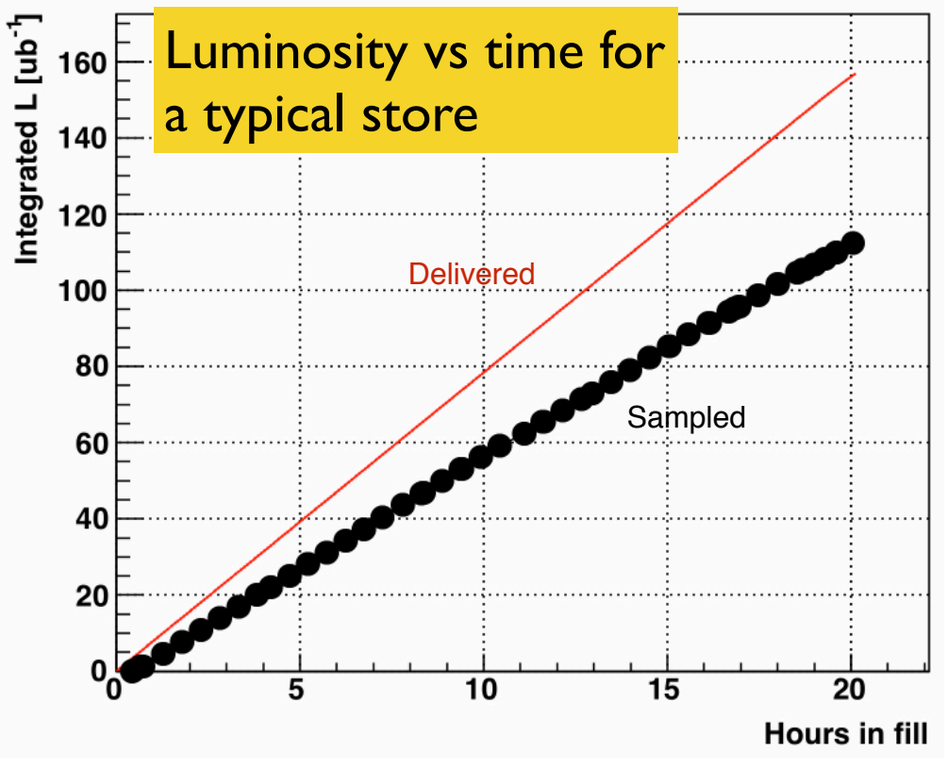
Data collection for isobar collisions: ZrZr,RuRu at $\sqrt{s}$=200 GeV

MB Events collected



Data taking hours/day





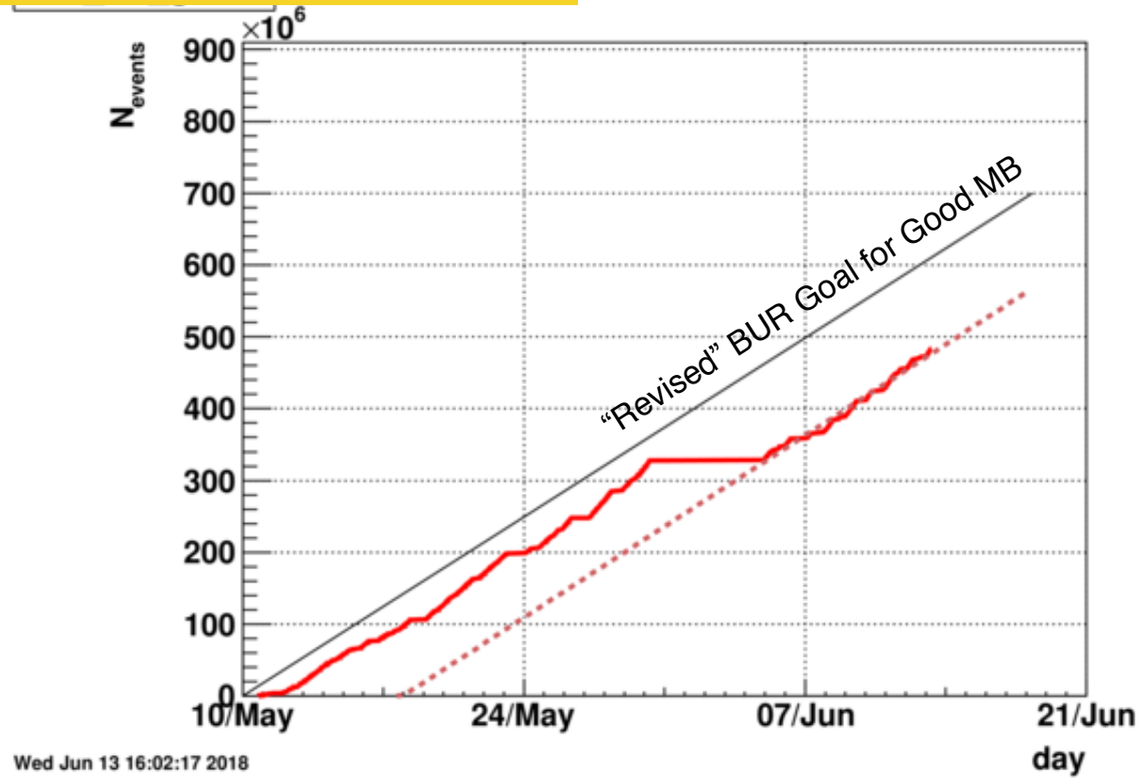
- 3.1B Min-Bias events for both RuRu, ZrZr collected (vs goal 1.5B) [3/15-5/9]
- good event fraction ~ 95%

Data taking for AuAu at $\sqrt{s_{NN}}$=27 GeV and Fixed target at $\sqrt{s_{NN}}$=3 GeV (and 7.2 GeV)

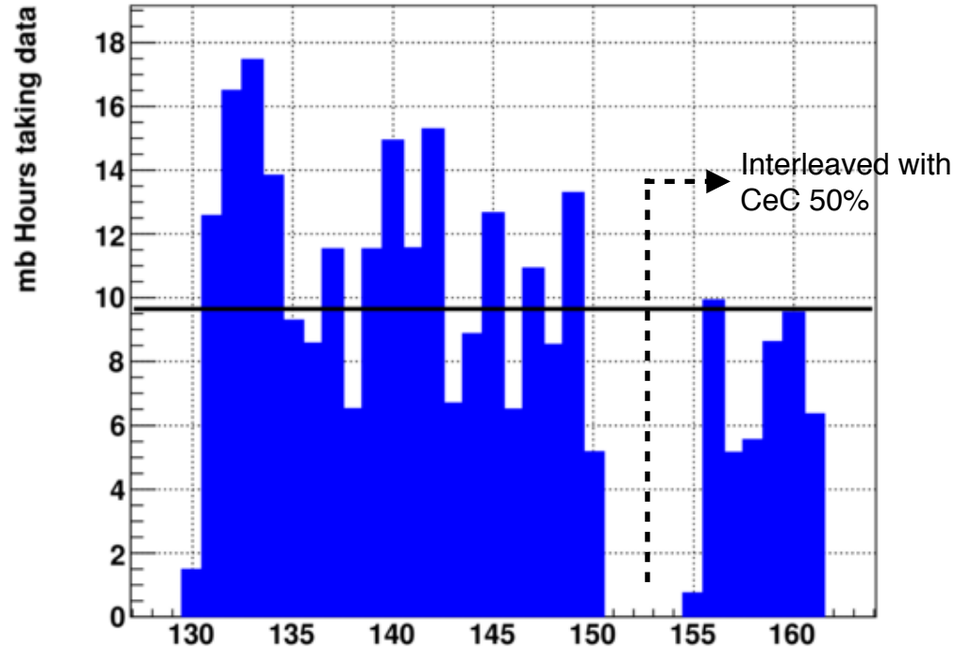
- **Au+Au at √sNN=27GeV**
  - Sampling full delivered luminosity
  - 1.5 hr store
  - Min-bias: VPD or ZDC or BBC+multiplicity with wide vertex cut (good event fraction ~55%)
- **Fixed Target (Au)**
  - 3.85 GeV Au beam ($\sqrt{s_{NN}}$=3 GeV): 0.5 hr store (Detectors stay on between stores)
    - 12 bunch beam
    - Rate tuning/leveling with beam vertical position and size
    - Min-bias: BBC+multiplicity (good event fraction ~90%)
  - 26.5 GeV Au beam ($\sqrt{s_{NN}}$=7.2 GeV) for CeC run
    - Collect data when the available for fixed target collisions at STAR
    - Same data taking configuration as fixed target with 3.85 GeV beam

Data collected for AuAu 27 GeV

Good MB Events collected



Data taking hours/day



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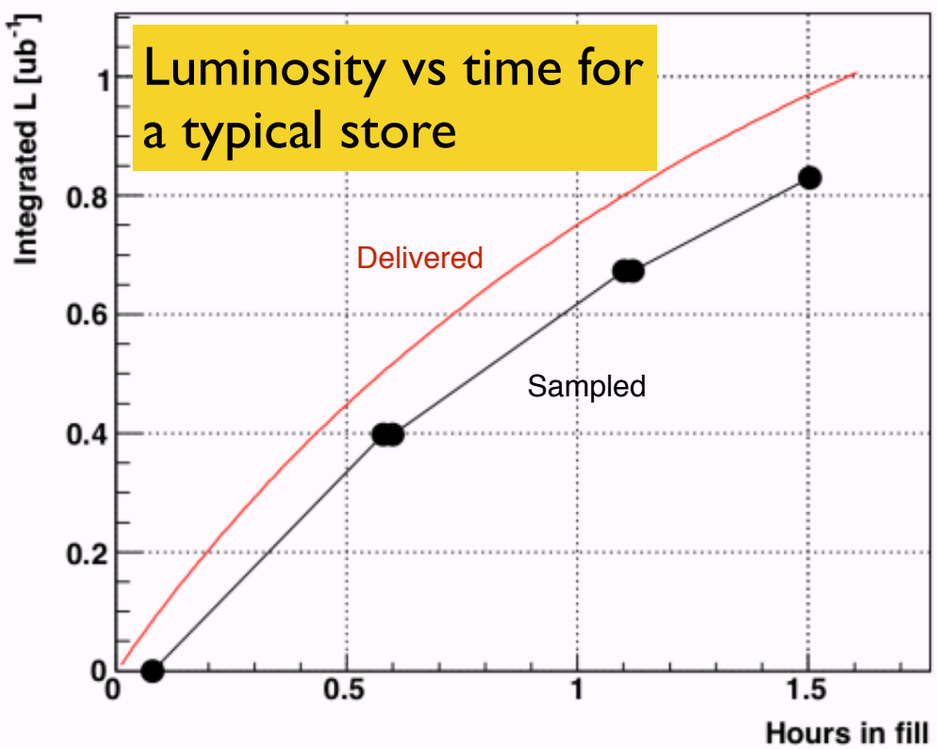
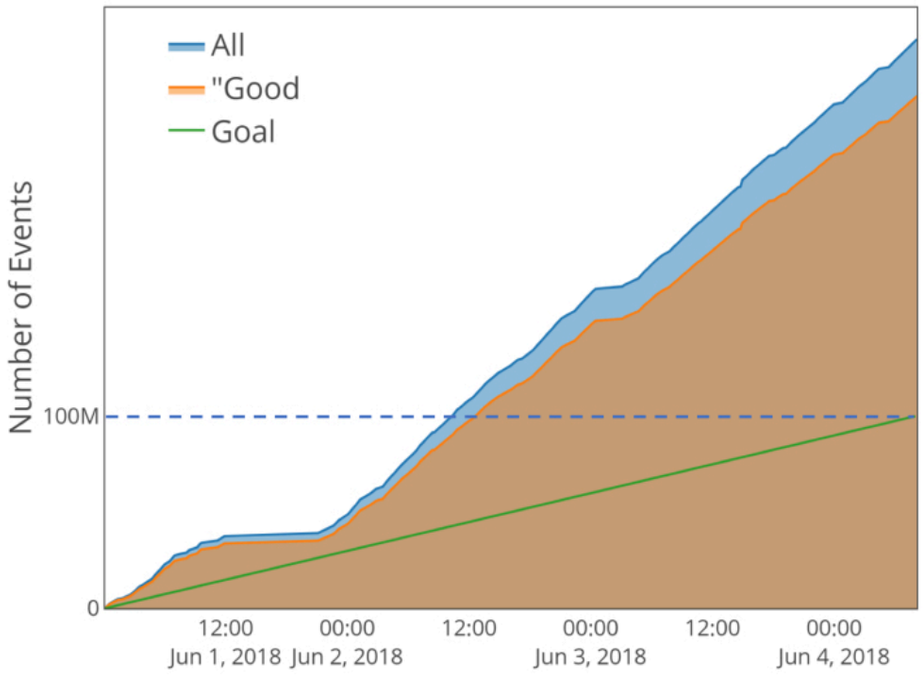
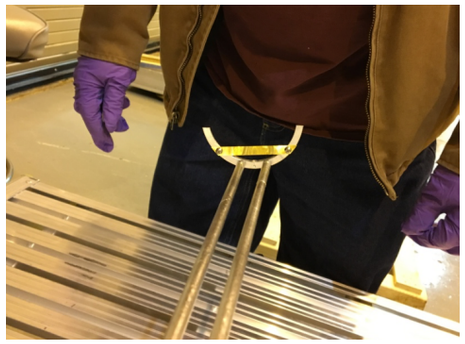
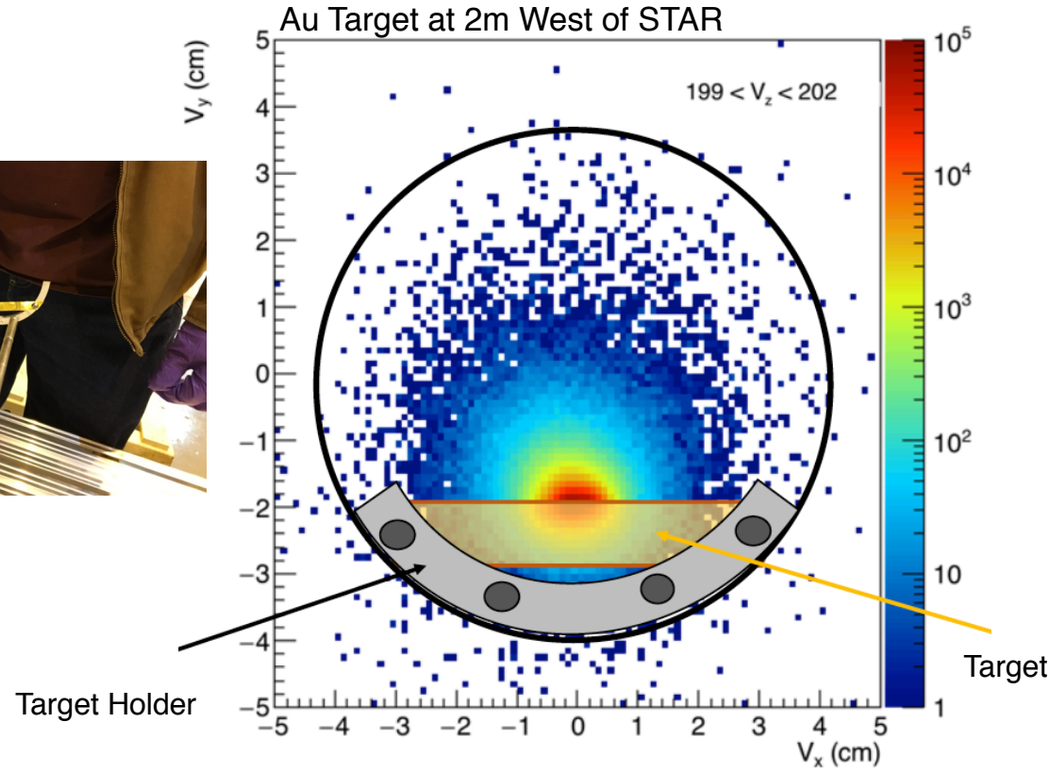


- 485M good min-bias events collected as of 6/13 (vs "revised" goal 700 M)
- FoM for global Lambda polarization: $R_{EP}*\sqrt{N}$ Great improvement in event plane resolution from EPD expected to bring the data set closer to the physics goal in BUR

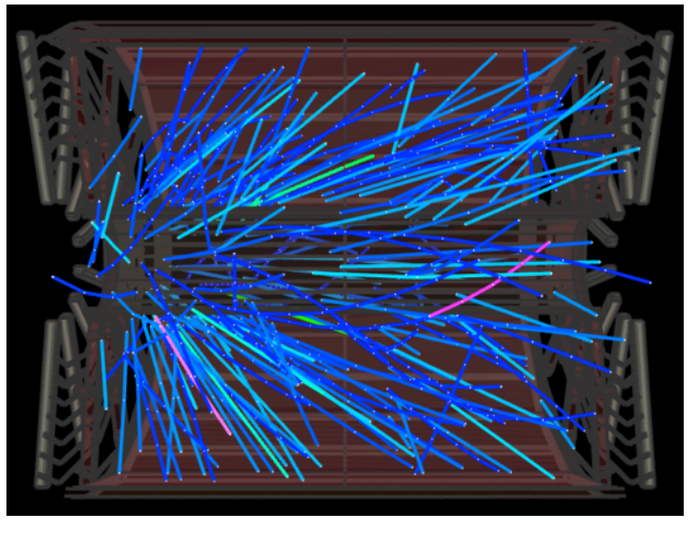
Data collection with fixed target



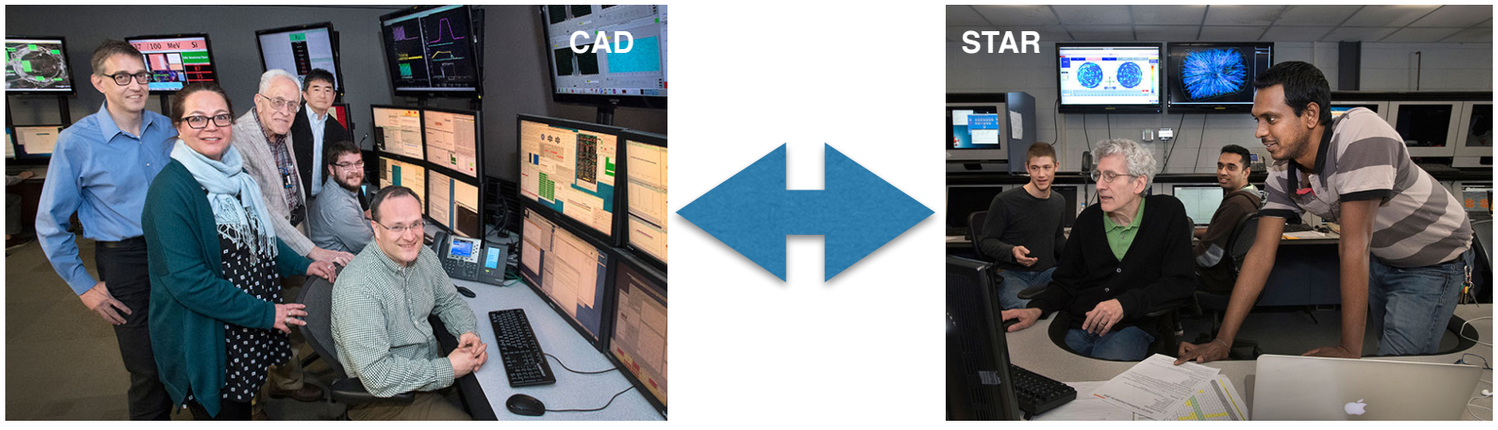




- 3.85 GeV Au beam on yellow [5/31-6/4]
  - 364M min-bias events collected
  - Good event fraction 90%
- 26.5 GeV Au beam during CeC run
  - 47M good min-bias events collected as of 6/13



Data taking with effective feedbacks



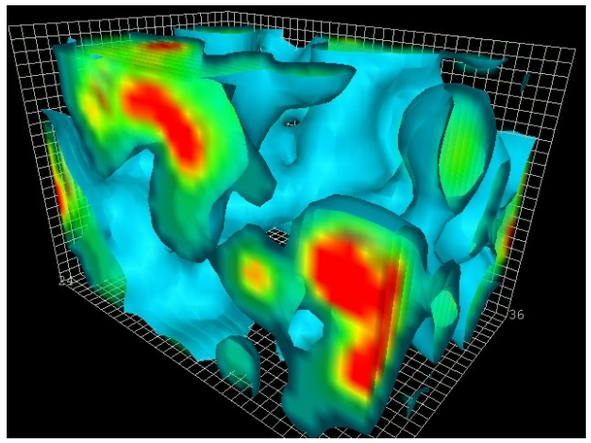
- Luminosity optimization
  - Collision rates, stability
- Minimizing background at STAR
  - ex: Resolving issues with unexpected background from gap cleaning
- Fast switching between species, beam energies
  - RuRu, ZrZr balancing
  - CeC (Au 26.5 GeV) / AuAu 13.5+13.5GeV
- Beam tuning on fixed target collisions
  - Using “good” event rates (from HLT/online tracking)

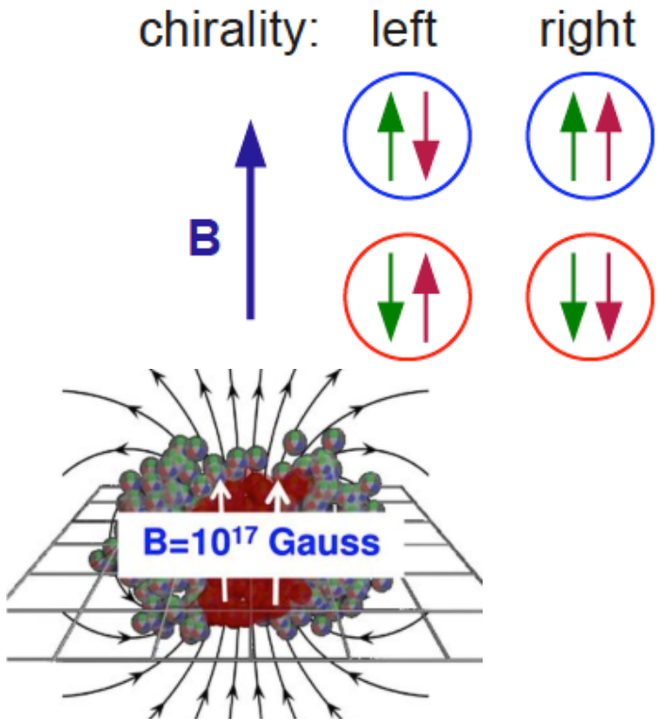
Run18 summary

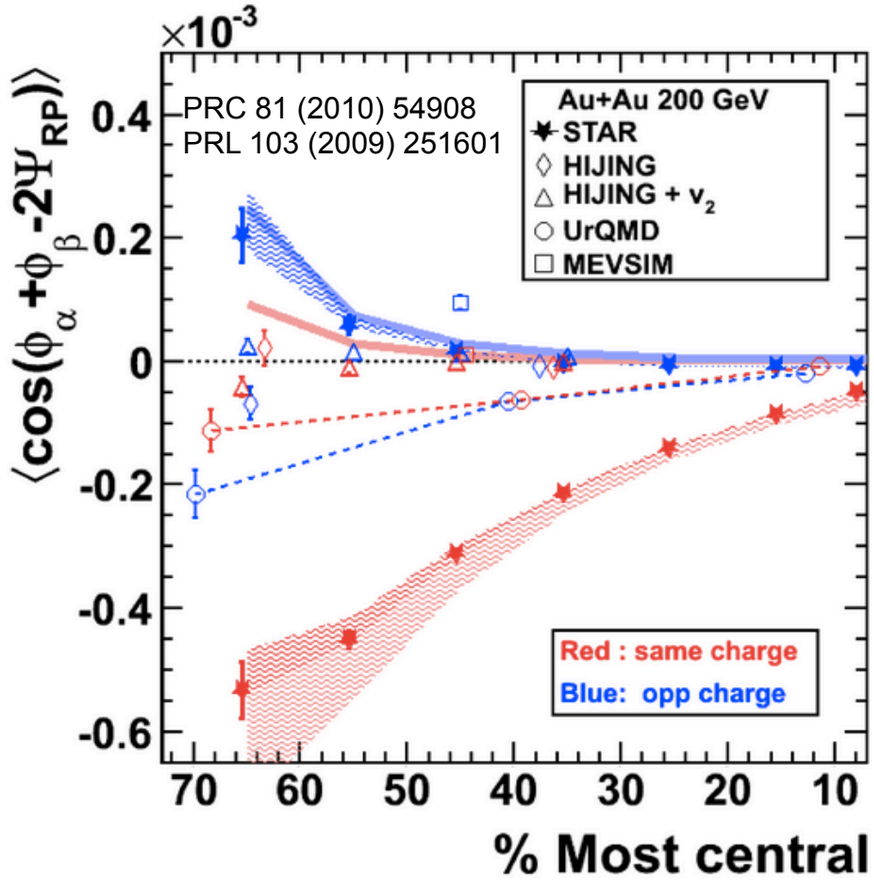
- Very successful operation and physics program in 2018 run
  - Exceeding the goals for isobar collisions at $\sqrt{s_{NN}}$=200 GeV (~240%) and fixed target at $\sqrt{s_{NN}}$=3 GeV (~300%) (expected to achieve 80% for $\sqrt{s_{NN}}$=27 GeV AuAu)
  - New sub-systems installed successfully commissioned
- Looking forward to exciting results from the high quality, high statistics data sets
- Thanks to CAD for the excellent performance

BACKUP Slides

Chiral Magnetic Effect



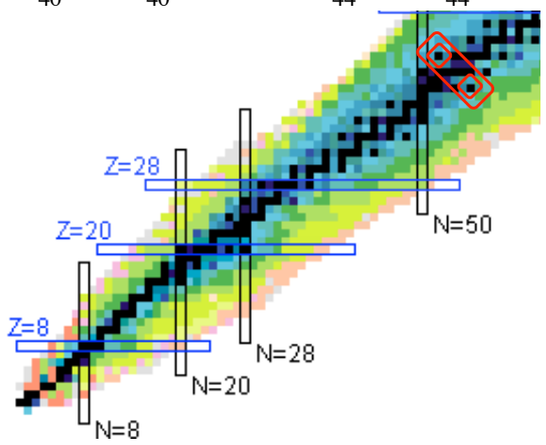


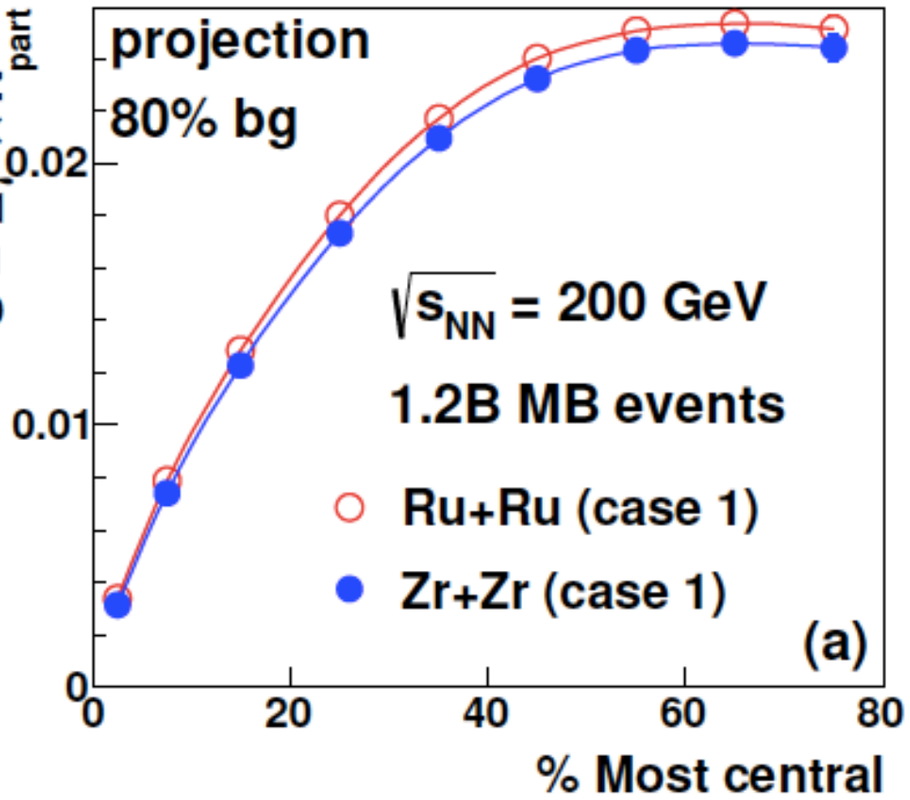


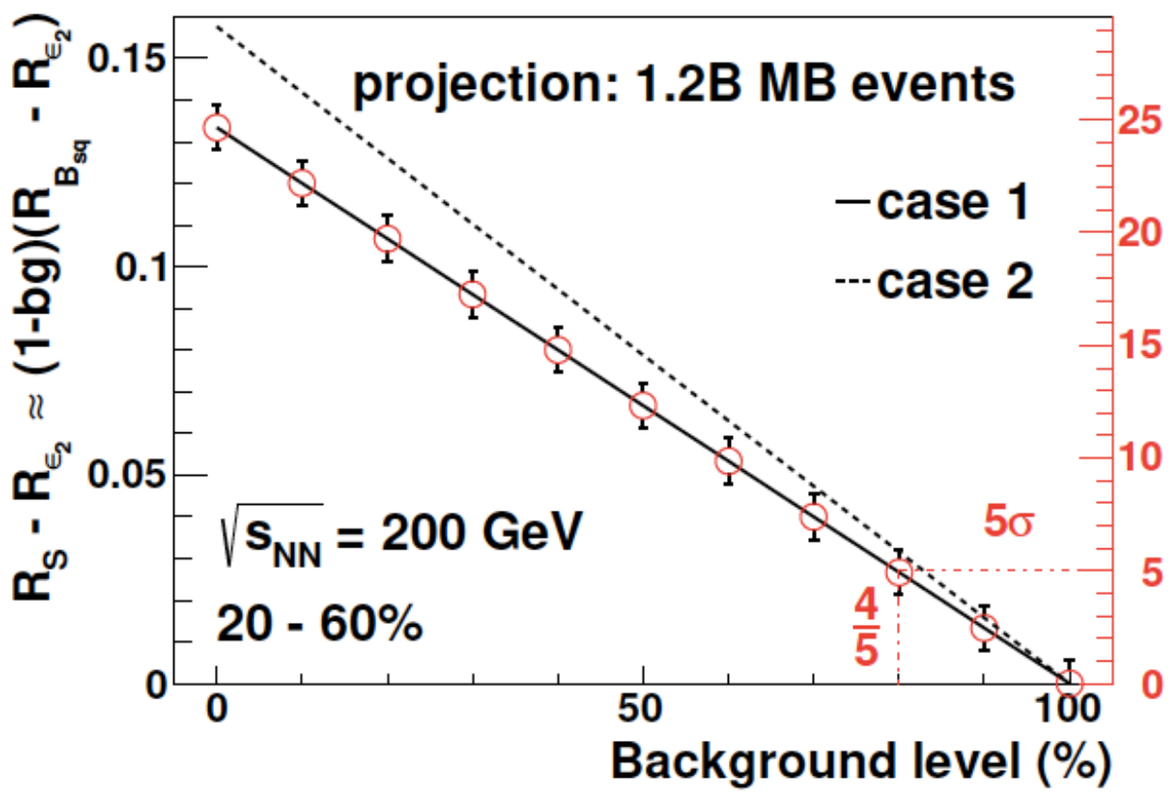
- Chiral Magnetic Effect: Chirally restored quarks with topological anomaly separated along magnetic field:
  - QCD Topological charge
  - Chiral symmetry restoration
  - Strong magnetic field
- Experimental observation: 2 particle charge correlation WRT reaction plane

CME: decisive test with isobars

$^{96}_{40}Zr + ^{96}_{40}Zr$ vs. $^{96}_{44}Ru + ^{96}_{44}Ru$

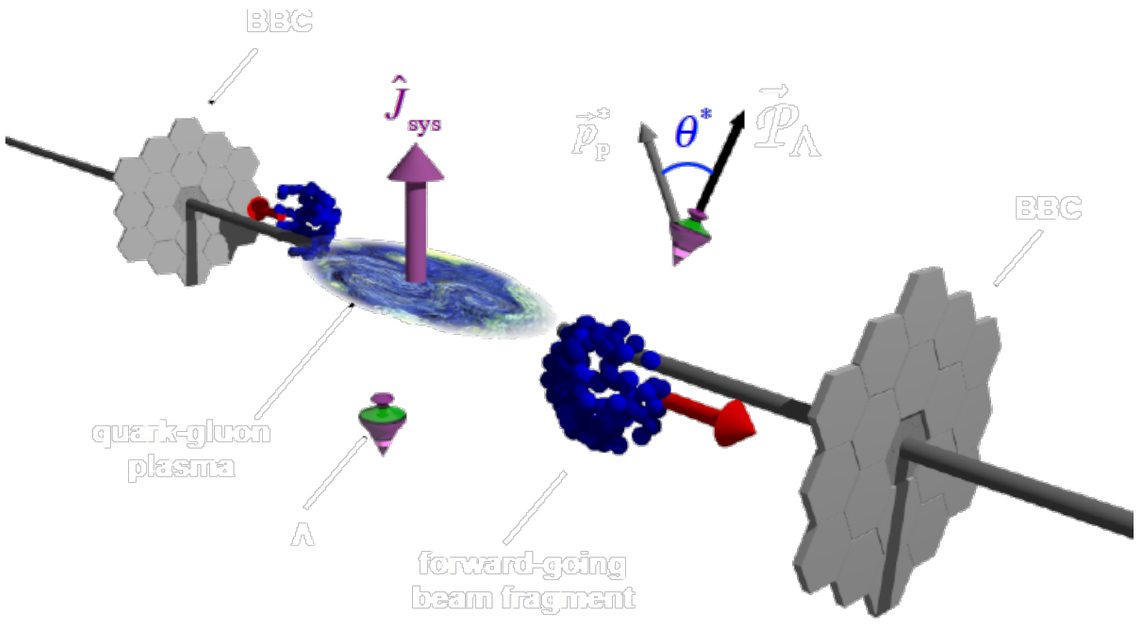


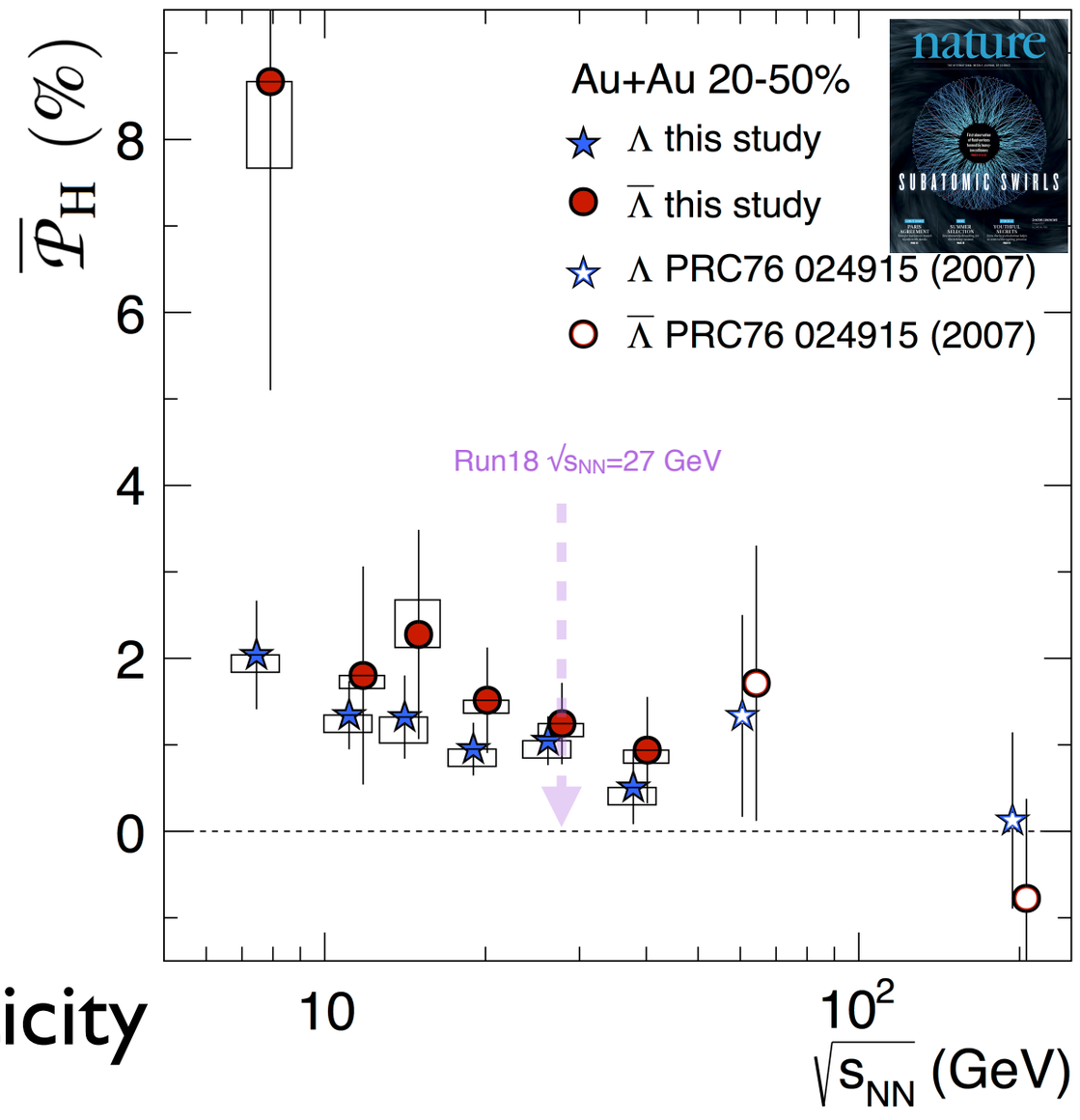




- Separate CME/background by changing magnetic field only, with all else constant
- 1.2B min-bias events each species: measurement with 5σ significance if 80% observed correlation is background

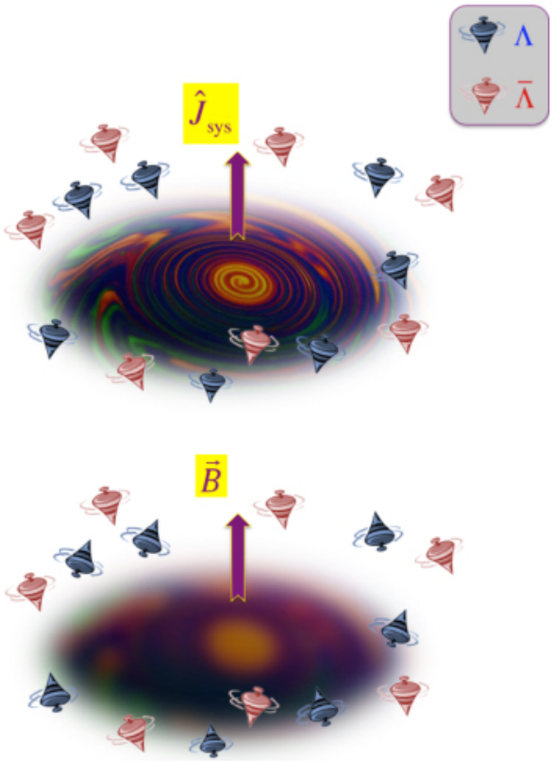
Global Hyperon Polarization

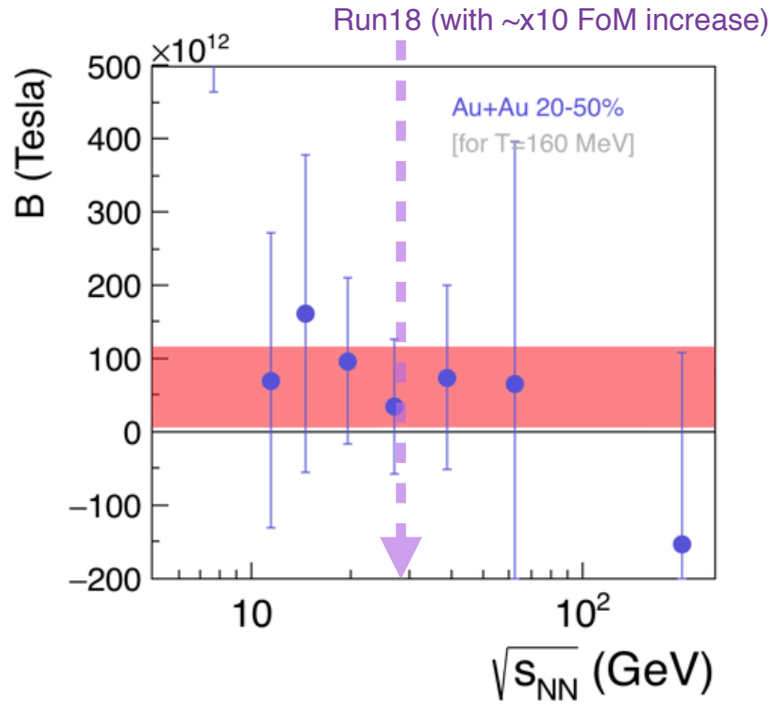




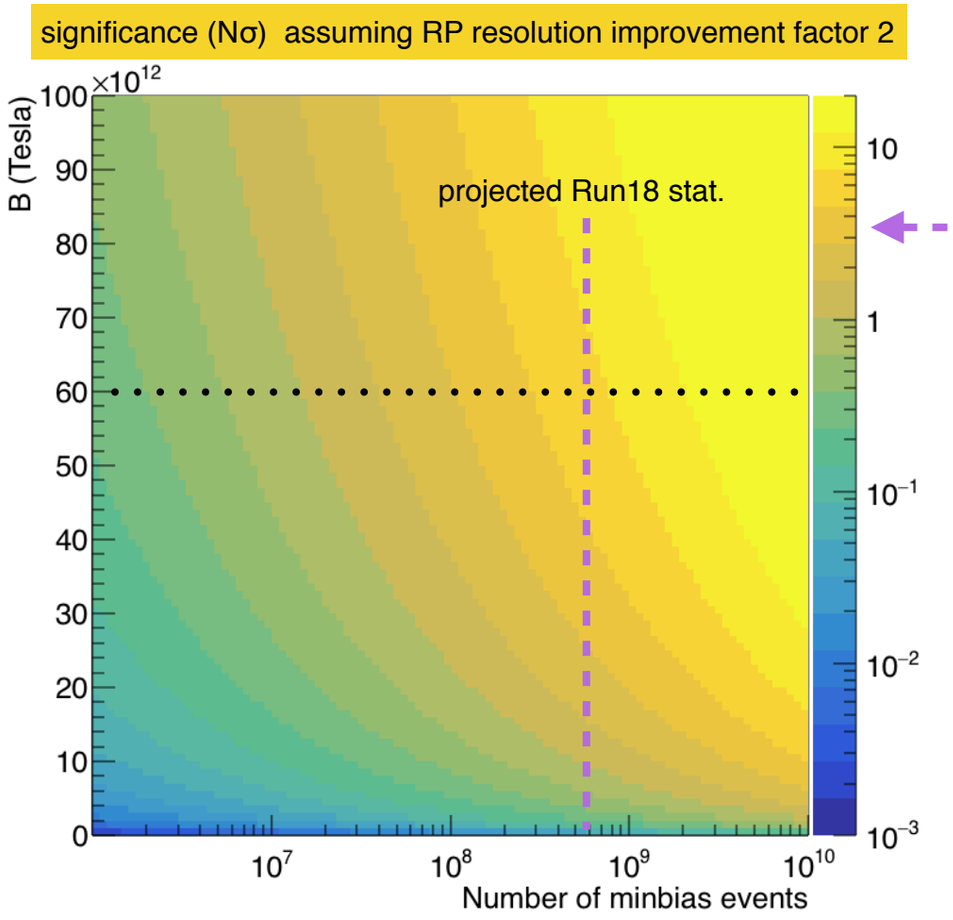
- New tool to study QGP and relativistic Quantum fluid vorticity
- Non-zero global angular momentum transfer to hyperon polarization

QCD fluid responds to external field

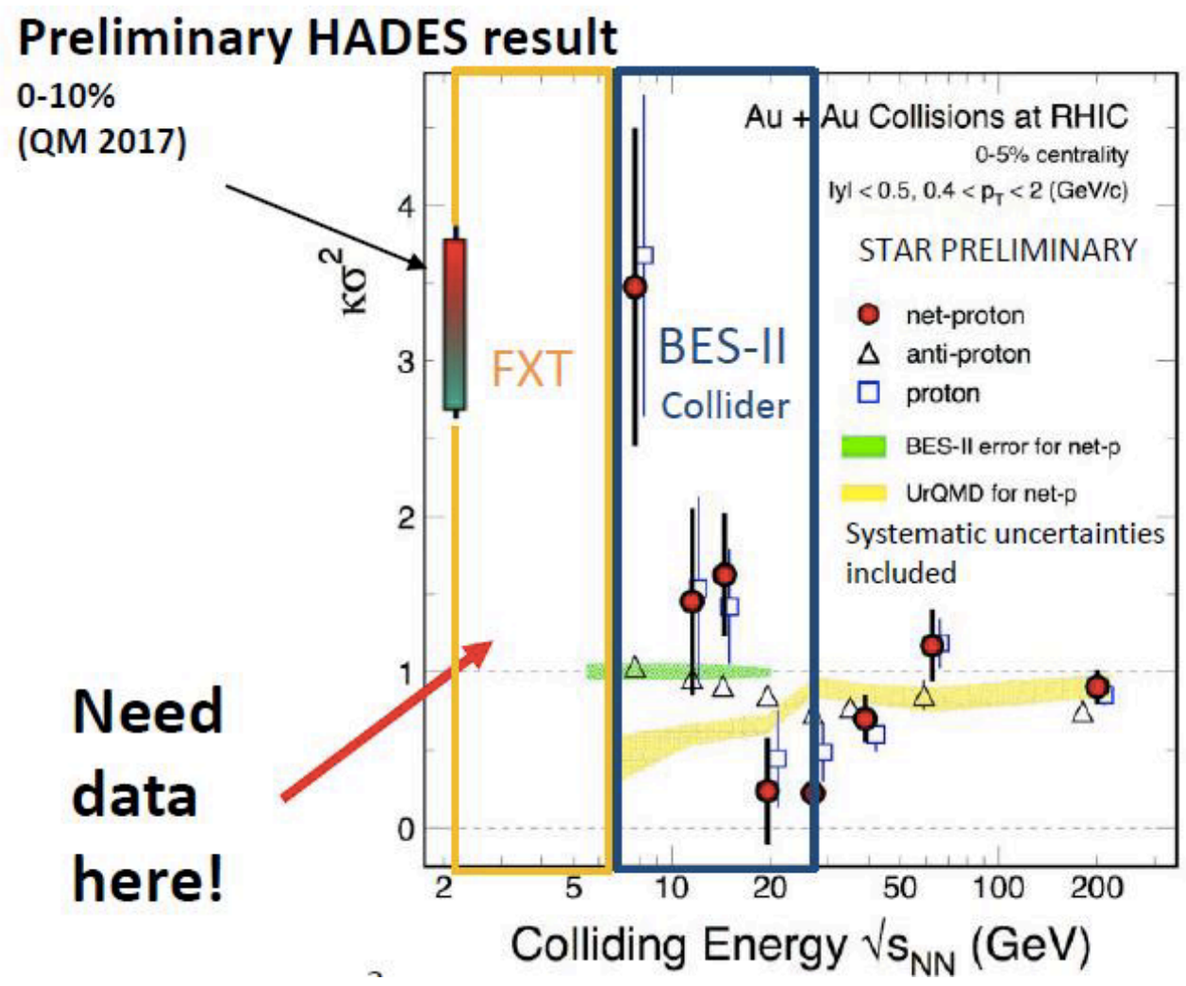


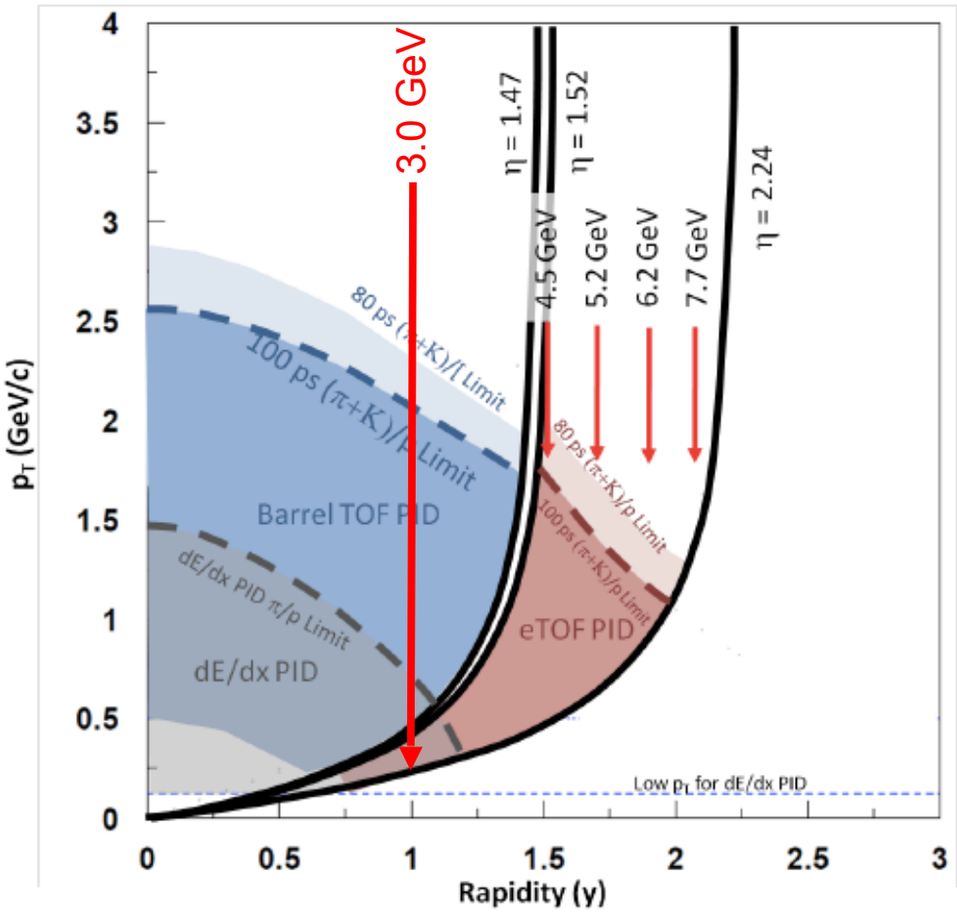


- Positive Global Hyperon Polarization indicating Vortical coupling
- Current data not able to distinguish Lambda/AntiLambda polarization difference due to Magnetic coupling)
- (potentially) Direct measure of Magnetic Field
- Need >~x10 more data + improvement in RP resolution (3σ at current central value)
  - FoM for polarization measurement $\delta\mathcal{P} \sim \frac{1}{R_{\mathrm{EP}}^{(1)} \times \sqrt{N}}$



Net-proton Fluctuation at low energies





For $\sqrt{s_{NN}}$=3 GeV midrapidity well within current acceptance

- Near critical point, correlation length diverges: enhancement of non-gaussian moments in net-proton distributions predicted
- With high statistics, establish a bridge between BES and world fixed target data